Influence of Monochromatic Light Exposure during Incubation and Rearing Stage on Carcass Traits and Meat Quality of Broilers

Mziray A. Juraji[1,3], Luckas O. Malachy[1], Justa J. Kashumba[1], Grace A. Mashele[1], Hilder C. Nyangi[2], Said H. Mbaga[1], Charles M. Lyimo[1]

[1]Department of Animal, Aquaculture and Range Sciences, College of Agriculture, Sokoine University of Agriculture, P.O. Box 3004, Chuo Kikuu, Morogoro, Tanzania
[2]Department of Business Management, College of Economics and Business Studies, Sokoine University of Agriculture, P.O. Box 3007, Chuo Kikuu, Morogoro, Tanzania
[3]Ministry of Livestock and Fisheries, P.O. Box 2870, Dodoma, Tanzania

Corresponding author: mzirayaj@gmail.com

SUMMARY

This study evaluated the effects of photo-thermal stimulation of broiler eggs and chicks, using different light wavelengths on carcass traits and meat quality of broiler chickens at market age. A total of 720 fertile broiler eggs were randomly assigned to three incubation light treatments from embryonic day one (ED1): green light (GL, 560 nm), blue light (BL, 480 nm), and darkness (control). After hatching, three parallel trials were conducted. In the first trial, day-old chicks (n = 240) from each treatment were reared under continuous photo stimulation matching the light intensity during incubation. In the second trial, chicks were brooded under their respective incubation light for two weeks, then exposed to conventional white light (WL). In the third trial, all chicks were reared under WL regardless of incubation light. All birds received standard diets, clean water, and vaccinations. Carcass traits (hot carcass weight, breast, thigh, drumstick, liver, heart, and abdominal fat) and meat quality parameters (pH, color, cooking loss, drip loss, and shear force) were recorded. Results showed that the BL and GL groups had significantly higher body and organ weights than WL. Dressing percentage peaked in BL (83.66%), while WL had the lowest (68.83%). Meat color (lightness L*) was higher in WL, indicating paler meat, while cooking and drip losses were also highest in WL, suggesting poor water-holding capacity. BL samples exhibited the lowest losses and shear force, reflecting better tenderness. Conclusively, photo stimulation using BL or GL, especially during early development, improves growth performance, carcass yield, and meat quality in broiler chickens.

Keywords: Photo stimulation, Broiler chickens, Carcass traits, Meat quality, Light spectrum.

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INTRODUCTION

Poultry production plays a vital role in global food security by providing a reliable and affordable source of high-quality animal protein in the form of meat and eggs. Broiler chickens have gained prominence in the poultry industry due to their rapid growth rate, feed conversion efficiency, and short production cycle, making them highly suitable for intensive and semi-intensive farming systems (Ke *et al.*, 2011; Mottet and Tempio, 2017). To further enhance production efficiency and meat quality, optimizing environmental and managerial factors, such as lighting, has become a critical focus in broiler management.

Among these factors, light management, commonly referred to as photo stimulation, has received considerable attention due to its profound effects on growth performance, behavior, stress regulation, and carcass characteristics (Olanrewaju *et al.*, 2006; Li *et al.*, 2020; Juraji et al., 2026). Photo stimulation involves controlled manipulation of the light spectrum, intensity, and photoperiod to influence physiological responses in poultry. Studies have shown that such manipulation affects melatonin secretion, circadian rhythms, feed intake, stress responses, and metabolic activity (Rozenboim *et al.,* 2004; Drozdova *et al.*, 2019).

In particular, the light spectrum, especially monochromatic blue (BL) and green (GL) light, has been shown to enhance broiler development and meat quality. Blue light has a calming effect that reduces bird activity and stress, resulting in improved feed efficiency and meat tenderness (Olanrewaju *et al.,* 2006; Zhang *et al.,* 2012). Green light has been associated with increased myogenesis and satellite cell proliferation during early development, thereby promoting muscle fiber growth (Zhang *et al.,* 2014; Dishon *et al.,* 2018). Compared to conventional white light (WL) or complete darkness, both BL and GL have been reported to improve immune response, muscle accretion, and overall broiler productivity (Rozenboim *et al.*, 1999; Helva *et al.,* 2019).

Photo stimulation has received considerable attention due to its profound effects on growth performance, stress regulation, and carcass characteristics (Olanrewaju et al., 2006; Li et al., 2020; Juraji et al., 2026). More recently, attention has turned toward *in-ovo* photo stimulation, where light exposure is introduced during embryogenesis. This approach has shown potential in entraining circadian rhythms, enhancing the somatotropic axis, and influencing post-hatch muscle development and carcass traits (Rozenboim *et al.,* 2004; Dishon *et al.,* 2017). However, the long-term effects of *in-ovo* and early post-hatch photostimulation, particularly on meat quality at market age, remain inadequately explored, with inconsistent results across studies and rearing conditions.

Meat quality is typically characterized by pH, color (L*, a*, b*), water-holding capacity, cooking loss, drip loss, and shear force (Zhao *et al.*, 2018; Baykalir *et al.*, 2020; Wu *et al.*, 2022). These attributes are significantly affected by pre-slaughter stress and metabolic changes, which may be influenced by light exposure. For example, stress can induce rapid glycolysis, leading to low pH and pale, soft, exudative (PSE) meat (Liu, 1998; Zhang, 2003). Understanding how photo stimulation interacts with physiological mechanisms affecting carcass traits and meat integrity is crucial for modern poultry production. This study was therefore designed to evaluate the effects of *in-ovo* and post-hatch photo thermal stimulation using blue, green and white light on carcass characteristics and meat quality of broilers at market age.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Poultry Research Unit of the Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture (SUA). The incubation room was maintained under standard artificial incubation conditions, while the rearing houses were naturally ventilated, deep-litter pens fitted with independent lighting circuits that allowed each pen to be assigned an independent light treatment without light contamination from neighboring pens. Ambient temperature in the rearing houses was monitored and maintained within the recommended thermoneutral range for the respective bird age, and litter, feeders, and drinkers were managed according to standard commercial brooding practice..

Experimental Design

The experiment followed a completely randomized design with three monochromatic light treatments including green light (GL, 560 nm), blue light (BL, 480 nm), and complete darkness (control, DL) applied from embryonic day one (ED1) of incubation. A total of seven hundred and twenty (n = 720) fertile broiler eggs obtained from a Harsho Group of Companies Ltd parent stock farm. Eggs were pre-weighed at the source and transported to the Department of Animal, Aquaculture and Range Sciences at SUA. Prior to incubation, all eggs were individually weighed, and only eggs with an average weight of 65 g (65 ± 2 g) were selected for use in the experiment. Selected eggs were placed on setter trays and incubated under standard conditions of 37.8°C and 56% relative humidity. From embryonic day one (ED1), eggs were randomly allocated to three incubation light treatments. The first group was exposed to green light (GL, 560 nm) provided by light-emitting

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diode (LED) lamps, the second group was incubated under blue light (BL, 480 nm) LED lamps, while the third group was incubated under complete darkness, serving as the control treatment throughout the incubation period.

The monochromatic light produced by LED lamps was mounted on the empty trays and positioned above the eggs in the light treatment group to evenly stimulate eggs at an intensity of 0.1 watts/m² at the eggshell surface level. Photo-stimulated eggs were illuminated on a regular interval of 15-minute light and 15-minute dark periods (Rozenboim *et al.,* 2004) using an installed timer. On day seven (ED 7), all eggs were candled, whereby the infertile eggs and dead embryos were excluded from the experiment. On ED18, all eggs were transferred to the hatching trays for hatching under the respective light treatment.

Post-hatch management

This experiment was carried out in three components, which ran in parallel. In the first trial, a total of two hundred and forty (n=240) hatched 1-day-old broiler chicks, obtained from hatched chickens, were used as experimental animals. Chicks were wing-tagged and raised in two rooms previously divided into six pens, each containing 20 broiler chicks. Each pen was illuminated (exposed) to three light treatments of green light (560 nm), blue light (BL 480 nm), and white light (WL). White light was provided throughout the experiment period (6 weeks). Chicks were allocated to their respective light treatment from incubation. Each room was illuminated with an artificial light source from an LED bulb placed 10cm above the chicken. The bulbs were expected to provide an intensity of 0.1 watts/m² at birds' heads-level.

The second trial was intended to check the effect of the light on meat quality and characteristics from the *in-ovo* to the brooding stage. A total of two hundred and forty (n=240) 1-day-old broiler chicks were randomly assigned to two rooms, which were initially partitioned into six pens of 20 chicks each. During brooding (2 weeks), the chicks were exposed to the light regime of the respective color from the incubation stage. The third trial intended to investigate the effect of light *in-ovo* photo stimulation on post-hatched chicks. All birds were raised under the conventional WL photo stimulation throughout the six (6) weeks post-hatched feeding trial. In all cases, chicks were fed commercial diets throughout the experimental period (5 weeks) and water was provided ad libitum. Vaccination for important diseases such as Newcastle and Gumboro was done at the appropriate time.

Determination of the effect of photo thermal stimulation on carcass characteristics and meat quality

At the end of each experiment, forty (n=40) broiler chickens from each light treatment group in each experiment were randomly selected for slaughter. Feed was withdrawn for 12 hours before slaughtering. Humane slaughtering procedures were used, and birds were allowed to bleed for 5 minutes postmortem, de-feathered, and eviscerated. Hot carcass weight (HCW) was recorded on all broiler chickens, and dressing percentage (DP) was correspondingly computed as a ratio of hot carcass weight to the body weight expressed in percentage (DP= HCW/BW) *100. Breast muscles were collected and weighed for evaluation of muscle growth. Likewise, breast muscles, thigh muscles, drumstick, liver, heart, and abdominal fat weight were taken for the determination of carcass characteristics. The obtained weight of the organs was expressed as the proportion of carcass weight.

Breast muscle pH was measured at 15 minutes postmortem using the left half. Following pH measurement, the muscle was weighed (W1), packed in polyvinyl plastic bags, sealed, and stored at 4ºC for 48 hours. After 48 hours of postmortem storage, breast muscles were blot dried with a clean paper towel and re-weighed (W2). Weight difference after 48 hours of postmortem storage was used to determine drip loss expressed as a proportion of the initial breast muscle weight. Also, the ultimate/final pH reading was re-recorded after 48 hours postmortem. Surface color was determined from the dorsal side of the left breast muscle at 48 hours postmortem using a Minolta spectrophotometer CM-2600d (Konica Minolta, Ramsey, NJ). The CIE, lightness (L*), redness (a*), and yellowness (b*) value system and an average of triplicate spectrophotometer readings were taken. The breast muscle samples were thereafter deep frozen for further meat quality analysis.

Frozen right breast muscle samples were thawed in the water bath at 30ºC for 20 minutes, blotted dry with a paper towel, and weighed before cooking (WBC). The samples were cooked at 75ºC for 1 hour in a thermostatically controlled water bath with a core temperature of 70°C. Cooked samples were allowed to cool under a tap running water at room temperature, thereafter removed from the bag, wiped with a clean paper towel, and re-weighed to obtain the weight after cooking (WAC). The difference in weight before and after cooking was used to compute cooking loss (%). Cooking loss was determined using the formula %CL = (WBC- WAC)/ WBC*100. Drip loss and cooking loss were used to determine the water-holding capacity of the breast meat samples. The cooked muscles were used for the evaluation of meat tenderness. In the determination of meat tenderness, cooked breast samples were sliced into blocks of 1cm × 1cm × 5 cm (width × height × length) perpendicular to the direction of muscle fibers. The blocks were sheared perpendicular to the direction of the muscle fibers at a crosshead speed of 100mm/min using a Warner-Bratzler shear force machine equipped with a flat, blunt-end blade. Each sample was sheared 3-4 times, and the maximum peak force (Fmax) for each muscle was recorded in Newtons (N).

Statistical analysis

All collected data were analyzed using one-way Analysis of Variance (ANOVA) in JMP statistical software to determine the effects of different light treatments on parameters of interest. Treatment means were compared using Tukey's Honest Significant Difference (HSD) test for multiple comparisons. Statistical significance was considered at $P < 0.05$. The following linear model was used to evaluate the effects of photo thermal stimulation on carcass traits and meat quality parameters:

$$Y_{ij} = \mu + T_i + \varepsilon_{ij}$$

Where:

Y_{ij} = Observation of the dependent variable (e.g., carcass weight, breast muscle pH, etc.) for the jth bird in the ith treatment group

μ = Overall mean

T_i = Fixed effect of the ith light treatment (i = 1, 2, 3 for BL, GL, and WL)

ε_{ij} = Random error term associated with the jth observation in the ith treatment, assumed to be independent and normally distributed with mean zero and constant variance ($\varepsilon_{ij} \sim (0, \sigma 2)$)

Ethical Approval

All animal-related procedures conducted in this study received ethical approval from Sokoine University of Agriculture (SUA), under research permit number DPRTC/R/186/59.

RESULTS

Effects of *In-Ovo* and Post-hatch monochromatic photo stimulation of broiler chicken on meat characteristics

Light treatment significantly affected most carcass and organ parameters measured (Table 1; P < 0.05), with the exception of gizzard weight, spleen weight, dressing percentage, and spleen percentage, which did not differ significantly among treatments. Among the parameters that did differ, broilers under blue light (BL) exhibited the highest values in fasting body weight, hot carcass weight, breast, thigh, and drumstick weights, with green light (GL) intermediate and white light (WL) lowest. Abdominal fat was significantly highest in WL and lowest in BL, while liver and heart weights were significantly greater in BL. Gizzard percentage was significantly higher in WL than in the other two treatments.

Effect of *In-Ovo* and Early Post-Hatch Photo Stimulation during Brooding (early stimulation) on broiler meat characteristics

All measured parameters differed significantly among the three light treatments in this trial (Table 2; P < 0.05). Broilers exposed to GL showed the highest fasting body weight, hot carcass weight (HCW), breast weight, and drumstick weight, while those under WL had the lowest values across all measured parameters; BL performed at an intermediate level for most traits. Thigh weight followed a different pattern, being highest in BL, followed by GL and WL. Gizzard, spleen, liver, and heart weights were all significantly higher in BL than in WL and GL, and abdominal fat was lowest in BL but highest in WL. Dressing percentage was significantly higher in BL than in GL and WL, and organ percentages (liver, heart, spleen, and gizzard) generally mirrored the pattern seen in absolute organ weights.

Table 1: Least square mean ± SEM for the effect of *In-Ovo* and post-hatch monochromatic photo stimulation of broiler chicken on meat characteristics

Treatment	BL	WL	GL	SEM	P-Value
Fasting BW (gm)	2193.97^{a}	1922.08^{c}	2130.56^{b}	17.866	0.0001
Hot Carcass W (gm)	1673.33^{a}	1465.96^{c}	1624.97^{b}	13.626	0.0001
Breast W (gm)	617.261^{a}	555.687^{c}	563.261^{b}	5.0362	0.0001
Thigh W (gm)	249.954^{a}	207.179^{c}	229.402^{b}	1.964	0.0001
Drum stick (gm)	206.387^{a}	168.905^{c}	187.596^{b}	1.6097	0.0001
Gizzard W	32.4312	33.2725	33.1381	0.28846	0.933
Spleen W (gm)	1.29167	1.125	1.125	0.07851	0.2299
Abdominal fat (gm)	19.399^{c}	27.1357^{a}	22.6872^{b}	0.21229	0.0001
Liver W (gm)	71.915^{a}	52.6692^{c}	61.4334^{b}	0.52936	0.0001
Heart W (gm)	9.95811^{a}	8.5647^{b}	8.52224^{b}	0.07866	0.0001
Dressing %	0.73782	0.7384	1.02272	0.164	0.377
Liver %	4.288^{a}	3.581^{b}	3.629^{b}	0.082	0.0001
Heart %	0.59^{a}	0.58^{a}	0.50^{b}	0.011	0.0001
Spleen %	0.077504	0.076867	0.066627	0.0053	0.276
Gizzard %	1.93361^{b}	2.26236^{a}	1.95731^{b}	0.044	0.0001

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at P < 0.05.

Table 2: Least square mean ± SEM for the effects of pre-and early post-hatch (during brooding) monochromatic photo stimulation on post-hatch broiler meat characteristics.

Treatment	BL	WL	GL	SEM	P-Value
Fasting BW	2033.62^{b}	1869.81^{c}	2142.54^{a}	19.819	0.0001
HCW	1551.03^{b}	1426.09^{c}	1634.1^{a}	15.116	0.0001
Breast W	571.441^{b}	551.507^{c}	618.825^{a}	5.71	0.0001
Thigh W	225.83^{a}	200.911^{c}	210.084^{b}	2.05	0.0001
Drum stick	189.54^{a}	164.455^{c}	172.21^{b}	1.69	0.0001
Gizzard W	36.146^{a}	30.706^{b}	27.785^{c}	0.298	0.0001
Spleen W	1.33^{a}	1.083^{b}	1.083^{b}	0.073	0.0001
Abdominal fat	23.12^{c}	26.86^{a}	25.95^{b}	0.246	0.0001
Liver W	59.311^{a}	45.893^{c}	51.9^{b}	0.505	0.0001
Heart W	9.567^{a}	7.419^{b}	9.549^{a}	0.087	0.0001
dressing %	77.64^{a}	76.27^{b}	76.34^{b}	0.328	0.0058
liver %	3.73^{a}	3.22^{b}	3.17^{b}	0.015	0.0001
Heart %	0.602^{a}	0.52^{c}	0.583^{b}	0.0024	0.0001
spleen %	0.084^{a}	0.076^{ab}	0.066^{b}	0.0049	0.0449
gizzard %	2.27^{a}	2.15^{b}	1.69^{c}	0.009	0.0001

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at a p-value < 0.005

Effect of *in-ovo* on post-hatched photo stimulation on meat characteristics

In-ovo exposure to the different monochromatic light treatments had significant effects on most broiler meat characteristics and organ development measured (Table 3; P < 0.05), with the exception of spleen weight, which did not differ significantly among treatments. Broilers from the BL and GL treatments showed significantly higher fasting body weight, hot carcass weight (HCW), and breast, thigh, and drumstick weights compared with the dark-incubated control (DL), with GL achieving the highest breast weight. Liver, heart, and gizzard weights were also significantly higher in the BL and GL groups. Abdominal fat was lowest in BL and highest in WL, and dressing percentage was highest in BL, followed by GL, with DL recording the lowest value. Spleen percentage and gizzard percentage showed minor but statistically significant variation among treatments.

Table 3: Least square mean ± SEM for the effects of *in-ovo* monochromatic photo stimulation on post-hatch broiler meat characteristics.

Treatment	BL	WL	GL	SEM	P-Value
Fasting BW	2265.98^{a}	2136.11^{b}	2262.68^{a}	19.087	0.0001
HCW	1773.024^{a}	1558.48^{b}	1739.229^{a}	24.085	0.0001
Breast W	658.28^{b}	612.57^{c}	711.76^{a}	9.634	0.0001
Thigh W	259.35^{a}	232.038^{b}	263.189^{a}	3.614	0.0001
Drum stick	255.161^{a}	174.637^{c}	204.613^{b}	2.914	0.0001
Gizzard W	35.58^{a}	31.27^{b}	35.146^{a}	0.485	0.0001
Spleen W	1.416	1.291	1.125	0.09	0.0784
Abdominal fat	23.95^{c}	30.75^{a}	27.3^{b}	0.358	0.0001
Liver W	57.058^{a}	47.315^{b}	56.055^{a}	0.773	0.0001
Heart W	12.46^{a}	7.5^{c}	9.88^{b}	0.144	0.0001
dressing %	83.66^{a}	68.83^{c}	77.20^{b}	1.157	0.0001
liver %	3.20^{a}	3.04^{b}	3.21^{a}	0.0055	0.0001
Heart %	0.69^{a}	0.48^{c}	0.56^{b}	0.001	0.0001
spleen %	0.0804	0.083	0.064	0.0055	0.049
gizzard %	1.99^{b}	2.006^{ab}	2.01^{a}	0.0035	0.016

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at P < 0.05.

Effect of *In-ovo* and post-hatch photo stimulation of broiler chicken on meat quality

The type of light exposure significantly influenced several meat quality parameters in broiler chickens (Table 4). During the first 48 hours post-mortem, muscle pH was highest in GL (6.03), followed by BL and WL. Lightness (L) was highest in BL (58.51) and lowest in WL (52.30), while redness (A) and yellowness (B) were significantly highest in BL and lowest in WL ($p < 0.0001$). After 48 hours, L values remained highest in WL (71.42), with GL lowest (64.37), and pH differences were not significant ($p = 0.4182$). Cooking loss was significantly higher in WL (21.3%) than in BL (18.6%) ($p = 0.0226$). Shear force was also significantly higher in WL (40.5 N) than in BL and GL (34.7 N), indicating tougher meat ($p < 0.0001$).

Effects of *In-Ovo* and Early Post-Hatch Photo Stimulation during Brooding (early stimulation) on broiler meat quality

Meat color during 48 hours postmortem showed significant differences in lightness (L), redness (a), and yellowness (b). BL and GL had higher L values (60.7 and 57.6) compared to WL (52.8) ($p < 0.0001$) (Table 5). Redness (a*) was highest in BL (2.035) and lowest in WL (0.844). Similarly, yellowness (b*) was highest in GL and BL (~4.0) and significantly lower in WL (1.53). After 48 hours, pH differed slightly but significantly ($p = 0.0283$), with BL having the highest value (4.98) and GL the lowest (4.71). Lightness (L) after 48h was highest in GL (61.04) and lowest in WL (55.98), while Redness (a) at 48h* peaked in WL (4.48), contrasting with its lowest initial value. Cooking loss was lowest in BL (19.63%) and highest in WL (25.08%) ($p = 0.005$). Shear force was significantly higher in WL (35.75 N), indicating tougher meat, while BL had the most tender (32.44 N) ($p = 0.0086$).

Table 4: Least square mean ± SEM for the effects of *In-ovo* and post-hatch monochromatic photo stimulation of broiler chicken on meat Quality.

Treatment	Treatment	BL	GL	WL	SEM	P-value
	Temp	36.57	35.95	36.75	0.413	0.3697
During 48hrs	pH	5.93^{b}	6.03^{a}	5.93^{b}	0.025	0.0072
	l	58.51^{a}	55.57^{ab}	52.304^{b}	0.976	0.0001
	a	2.237^{a}	1.591^{b}	0.982^{c}	0.014	0.0001
	b	4.009^{a}	2.647^{c}	3.327^{b}	0.192	0.0001
After 48hrs	pH	7.09	5.22	5.04	1.208	0.4182
	l	69.005^{ab}	64.37^{b}	71.416^{a}	1.604	0.0095
	a	1.764	1.46	-20.121	12.2	0.352
	b	7.79	8.463	8.222	0.583	0.712
Cooking loss		18.66^{b}	18.83^{ab}	21.37^{a}	0.758	0.0226
Drip loss		5.208	5.79	6.291	0.378	0.135
Shear force		34.74^{b}	34.76^{b}	40.53^{a}	0.922	0.0001

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at P < 0.05.

Table 5: Least square mean ± SEM for the effects of pre-and early post-hatch (during brooding) monochromatic photo stimulation on post-hatch broiler meat Quality

	Treatment	BL	GL	WL	SEM	P-value
	Temp	34.69	34.83	34.77	0.447	0.9751
During 48hrs	pH	5.791	5.687	5.73	0.075	0.6256
	L	60.705a	57.617a	52.811b	1.11	0.0001
	A	2.035a	1.329b	0.844c	0.134	0.0001
	B	4.045a	4.474a	1.525b	0.2946	0.0001
After 48hrs	pH	4.975a	4.712b	4.743ab	0.0745	0.0283
	L	59.725ab	61.04a	55.975b	1.302	0.0213
	A	2.828b	2.119b	4.481a	0.4248	0.0007
	B	6.86	9.64	5.59	1.95	0.3279
Cooking loss		19.63b	23.29ab	25.08a	1.16	0.005
Drip loss		5.54	5.66	6.33	0.248	0.0605
Shear force		32.44b	34.04ab	35.75a	0.733	0.0086

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at P < 0.05.

The effect of *in-ovo* on post-hatched photo stimulation on meat characteristics

Lightness (L*) was significantly higher in the WL group (55.51) compared to BL (49.81) and GL (51.91) during the first 48 hours, indicating paler meat in dark-incubated birds. After 48 hours, L* increased further, especially in GL (71.82), suggesting better light reflection. Redness (a*) and yellowness (b*) values did not significantly differ across treatments, though WL tended to have slightly redder meat after 48 hours. Significant differences were found in cooking loss, drip loss, and shear force, with WL birds showing the highest cooking loss (27.71%) and drip loss (6.83%), reflecting poor water-holding capacity. Conversely, BL birds had the lowest losses and shear force values confirmed tougher meat in WL (40.44 N), while BL and GL treatments resulted in more tender meat (35 N).

Table 6: Least square mean ± SEM for the effects of *in-ovo* monochromatic photo stimulation on post-hatch broiler meat quality

	Treatment	BL	GL	WL	SEM	P-value
	Temp	35.79	35.73	36.35	0.258	0.1813
During 48 HRS	pH	6.062	6.058	6.012	0.035	0.5542
	L	49.807^{b}	51.91^{b}	55.511^{a}	0.735	0.0001
	A	1.549	1.58	1.202	0.125	0.0685
	B	3.429	3.227	2.861	0.219	0.1863
After 48HRS	pH	5.265	5.145	5.137	0.048	0.4072
	L	62.181^{b}	71.821^{a}	66.27^{ab}	1.891	0.0025
	A	1.269	1.51	2.325	0.414	0.1769
	B	6.404	8.099	7.047	0.547	0.0945
Cooking loss		21.45^{b}	23.71^{b}	27.71^{a}	0.823	0.0001
Drip loss		5.33^{b}	6.21a^{b}	6.83^{a}	0.365	0.018
Shear force		35.26^{b}	35.41^{b}	40.44^{a}	0.843	0.0001

The data were analyzed using one-way ANOVA, and means were compared with Tukey-Kramer HSD. Results are presented as mean ± SEM. Superscripts (a, b, c, d) indicate significant differences at P < 0.05.

DISCUSSION

The present study provides compelling evidence that monochromatic light exposure during incubation and early post-hatch rearing exerts profound and lasting effects on carcass characteristics and meat quality of broiler chickens. In particular, blue (BL) and green light (GL) consistently outperformed white light (WL) across most growth, carcass yield, and meat quality parameters. These findings strongly support previous reports that light spectrum acts as a powerful non-nutritional environmental modulator of growth and muscle development in broilers (Rozenboim et al., 2004; Olanrewaju et al., 2006; Wang et al., 2020).

The superior fasting body weight, hot carcass weight, breast, thigh, and drumstick weights observed under BL and GL treatments indicate enhanced muscle accretion compared with WL. Similar improvements in carcass traits under short-wavelength light have been reported in earlier studies, which demonstrated that green and blue light stimulate myogenic activity during embryogenesis and early post-hatch development (Rozenboim et al., 2004; Zhang et al., 2014; Wang et al., 2020). Green light exposure during incubation has been shown to increase satellite cell proliferation and alter gene expression linked to muscle hypertrophy, mediated through activation of the somatotropic axis, including growth hormone and IGF-1 concentration (Zhang et al., 2014). This mechanistic pathway provides a strong biological explanation for the enhanced breast muscle development observed in GL-treated birds in the present study.

Blue light, by contrast, appears to exert its effects primarily through behavioral and metabolic modulation. Broilers reared under BL exhibit reduced locomotor activity, lower fear responses, and calmer behavior, which translates into reduced energy expenditure and improved nutrient partitioning toward muscle growth (Prayitno et al., 1997; Olanrewaju et al., 2006; Remonato Franco, 2022). This behavioral adaptation likely contributed to the higher dressing percentage and improved carcass yield observed under BL treatment. The consistently lower abdominal fat deposition in BL-exposed birds further supports the hypothesis that blue light improves energy partitioning toward lean tissue accretion. Reduced fat deposition under BL may be attributed to lower stress-induced corticosterone secretion and more stable metabolic homeostasis (Rozenboim et al., 2004), aligning with the present findings. In contrast, birds reared under WL exhibited significantly higher abdominal fat, suggesting less efficient nutrient utilization and greater metabolic stress.

The enhanced liver and heart weights observed under BL and GL treatments suggest improved metabolic and cardiovascular capacity, essential for sustaining rapid muscle growth. The liver plays a central role in protein synthesis and lipid metabolism, while heart development reflects circulatory efficiency. Similar physiological enhancements under monochromatic light exposure have been reported in broilers and are often associated with improved oxygen delivery and metabolic efficiency (Wang et al., 2020). The lack of consistent differences in spleen weight among treatments suggests that photo stimulation primarily targets growth and metabolic pathways rather than lymphoid organ hypertrophy. However, previous studies indicate that blue and green light may enhance immune competence functionally, even in the absence of morphological changes (Olanrewaju et al., 2006; Helva et al., 2019a; Remonato Franco, 2022).

Meat pH is a critical determinant of meat quality, influencing color, water-holding capacity, and tenderness. The higher early postmortem pH observed in BL- and GL-treated birds indicates a slower rate of postmortem glycolysis, which is desirable for preventing excessive lactic acid accumulation and pale, soft, exudative (PSE) meat (Ali et al., 2008). The more stable pH decline observed under BL and GL suggests reduced pre-slaughter stress and improved physiological stability. Blue light exposure has been linked to lower fear responses and reduced corticosterone levels, preserving muscle glycogen reserves prior to slaughter (Rozenboim et al., 2004; Remonato Franco, 2022). This physiological advantage likely contributed to improved meat quality traits in the present study, and is consistent with reports that pre-slaughter handling and stress are key determinants of postmortem meat quality outcomes (McKee et al., 2009).

Meat color is one of the most important quality traits influencing consumer acceptance. The higher lightness (L*) values observed in WL-treated birds indicate paler meat, often associated with protein denaturation and poor water-holding capacity (Ali et al., 2008). In contrast, BL- and GL-treated birds exhibited more desirable color attributes, consistent with previous findings on monochromatic light effects on meat pigmentation and muscle structure (Pan et al., 2011; Wang et al., 2020). The increased cooking and drip losses observed in WL-treated meat further confirm inferior water-holding capacity, while reduced losses under BL and GL suggest better preservation of myofibrillar proteins and membrane integrity (Pan et al., 2011; Wang et al., 2020). Zhao et al. (2018) reported that excessive moisture loss during storage and cooking is indicative of protein denaturation and compromised muscle structure. The reduced cooking and drip losses observed under BL, and to a lesser extent GL, suggest better preservation of myofibrillar proteins and cell membrane integrity. These findings are consistent with previous reports demonstrating improved meat juiciness and structural stability under monochromatic light exposure (Zhang et al., 2012; Baykalir et al., 2020), reinforcing the role of light spectrum in postmortem muscle biochemistry.

Tenderness, as assessed by Warner–Bratzler shear force, was significantly improved under BL and GL treatments. Lower shear force values reflect enhanced myofibrillar fragmentation and reduced connective tissue resistance, contributing to superior eating quality. Reduced stress and calmer behavior under BL likely minimize muscle fiber damage during growth, thereby improving meat tenderness (Prayitno et al., 1997; Remonato Franco, 2022). Improved water-holding capacity under BL and GL further contributes to tenderness by maintaining muscle hydration and limiting protein cross-linking during cooking (Pan et al., 2011). These results underline the multifactorial influence of light spectrum on postmortem muscle biochemistry and texture.

Collectively, the findings demonstrate that *in-ovo* and early post-hatch photo stimulation using blue and green monochromatic light represents a practical, low-cost, and non-invasive strategy for improving carcass yield and meat quality. Importantly, these benefits were achieved without dietary or genetic modification, aligning with earlier findings in controlled and commercial systems (Rozenboim et al., 2004; Olanrewaju et al., 2006; Juraji et al., 2026). Under tropical conditions, where heat stress and management constraints often limit broiler performance, optimized lighting regimes, particularly blue and green photo stimulation offer a sustainable strategy to enhance productivity, meat quality, and animal welfare. Integrating these light spectra into commercial hatchery and broiler operations can improve efficiency while delivering greater economic returns.

CONCLUSION

In conclusion, monochromatic blue and green light exposure during incubation and early rearing stages significantly enhances carcass traits, reduces fat deposition, improves meat quality, and yields more tender and visually appealing broiler meat. These effects are mediated through a combination of hormonal regulation, metabolic efficiency, stress reduction, and improved muscle development. The study provides strong scientific justification for incorporating targeted photo stimulation into modern broiler production systems, particularly in tropical and resource-limited environments.

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Conflict of Interest

Authors do not have any conflict of interest.

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